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RADIO COMMUNICATIONS BY MEANS OF VERY SHORT ELECTRIC WAVES

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A reprint of a Paper read before the Royal Institution of Great Britain, on Friday, December 2nd, 1932.

DURING the last twelve months, a good deal of attention, both scientific and popular, has been directed to the published accounts—of varying degrees of accuracy—of my recent researches regarding the use and potentialities of very short electric waves for radio communication over relatively long distances. My object to-night is to give you facts about the results obtained and the observations made by myself and my assistants, and to furnish some description of the apparatus used and of the methods employed.

The study of what may be termed " very short " waves dates from the discovery of electric waves themselves, i.e., from the time of the classical experiments of Hertz and his contemporaries some 42 years ago. In many of these experiments Hertz used very short electric waves, and conclusively proved that these waves followed the same laws as waves of light as regards speed of propagation, reflection, refraction and diffraction.

The problem of utilisation of very short waves for wireless communication is not a new one to me, for I have devoted to it much thought and labour since the time of my earliest wireless experiments 38 years ago. In 1896 I was able to demonstrate to the Engineers of the Post Office that waves of the order of 30 centimetres—corresponding to a frequency of approximately one million kilocycles, and now sometimes termed micro-waves—could be successfully used for telegraphic communication over a distance of $1\frac{3}{4}$ miles by employing suitable reflectors. Later this distance was increased to $2\frac{1}{2}$ miles. These early results were described by the late Sir William Preece at a Meeting of the British Association in September, 1896, and at subsequent lectures, and were referred to in greater detail in a Paper which I read before the Institution of Electrical Engineers on the 3rd of March, 1899. At that lecture I demonstrated how it was possible, by means of " very short " waves, for reflectors to concentrate transmission in a given direction instead of allowing the waves to spread in all directions.

At that time, however, the use of these very short waves did not appear very promising, and for many years my investigations—like those of my contemporaries—were directed to the use of progressively longer waves which reached the length of ten thousand metres.

In 1916, war requirements called for methods of radio communication more secret than those which were then in use, and re-opened the interest of the directive properties inherent in the very short waves, and I again turned my attention and investigations to the generation and reception of very short waves. I am indebted to the valuable assistance which I received then from Mr. C. S. Franklin, of the Marconi Company.

At that time, using special spark transmitters and a two metre wavelength, six miles of reliable communication was secured ; and later tests with the same wavelength, carried out at Carnarvon, gave good signals at a distance of over 20 miles, with the indication that a greater range would have been possible.

The remarkable results which I obtained during the period 1919-1924* with the use of wavelengths from 100 to 6 metres—which led to the collapse of the long wave Imperial scheme and its substitution by high speed short wave Beam Marconi Stations, and in fact brought about the present radio revolution of short wave long distance radio telegraph and telephone services—again distracted my attention from the study of micro-waves.

Electro magnetic waves under one metre in length are usually referred to as Quasi-Optical waves, the general belief being that with them communication is possible only when the two ends of the radio circuit are within visual range of one another ; and that consequently their usefulness is defined by that condition.

Long experience has, however, taught me not always to believe in the limitations indicated by purely theoretical considerations or even by calculations, for these—as we well know—are often based on insufficient knowledge of all the relevant factors, but, in spite of adverse forecasts, to try out new lines of research however unpromising they may seem at first sight.

It was about 18 months ago that I decided again to take up the systematic investigation of the properties and characteristics of these very short waves in view of the palpable advantages which they seemed to offer—i.e., the small dimensions of the radiators, receivers and reflectors necessary for radiating and receiving a

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* Paper read American Institute of Electrical Engineers, on 20th June, 1922—Proc. Institute of Radio Engineers, New York, Vol. X, No. 4, August, 1922.

Results obtained over very long distances by Short Waves and Directional Wireless Telegraphy. Journal Royal Soc. Arts, Vol. 72 (1924), p. 607.

Radio Communications—idem. Vol. 73, p. 121.

Radio Commiuncations—Paper read before Institute of Civil Engineers, 26th October, 1926—Vol. 222. Session 1925-1926, Part 2.

Le Radiocommunicazioni a Fascio-Nuova Antologia Rome, 16th November, 1926.

Radio Communications—Paper read before American Institute of Electrical Engineers and the Institute of Radio Engineers, New York City, October 17, 1927.

considerable amount of electrical energy—and in view also of the fact that they do not suffer interference from natural electrical disturbances such as atmospherics.

It was, of course, obvious to me that these investigations would be facilitated if it were possible efficiently to utilise considerably more power in the transmitters, and employ more reliable and practical receivers than those that were then available. I also decided to resume these researches in Italy where, as President of the National Research Council, I enjoyed special facilities. I may also add that I was afforded every possible assistance and encouragement by the Italian Government.

Most of the research necessary for the construction of the new apparatus employed on these tests has been carried out by my personal assistant, Mr. G. A. Mathieu. His work, aided by suggestions and observations of my own, has resulted in the possibility of generating and radiating very short waves of greater power than hitherto, and in the elaboration and construction of practical and easily adjustable receivers. I am also indebted to Mr. G. A. Isted, of the Marconi Company, for much valuable work.

At the beginning of our work a choice had to be made between two alternative ways of attacking the problem—by the Magnetron, or the Electron Oscillator. As a powerful transmitter was the principal aim, the Magnetron road was a very tempting one ; but the necessity of employing rather high potentials, of producing an auxiliary field, and doubts of being able to ensure good modulation, made us prefer the Barkhausen-Kurz effect.

Nor less important was the choice of the wavelength to be employed. Since it appeared improbable that there would be any great difference in the propagation properties of waves of say 80 to 20 centimetres, we decided first to concentrate our efforts on the generation and efficient radiation of what may be termed a medium wavelength on the micro-wave scale—that is a wavelength of the order of half a metre, i.e., 600,000 kilocycles.

The first circuit tried was of the well-known Barkhausen and Gill Morell plate grid Lecher wire type, which has been used in nearly all recent experiments. In that circuit we tried—with varying success—all the new and obsolete receiving and amplifying valves of the cylindrical plate type that were available ; but as soon as any was pressed for power, its life proved to be only a matter of minutes.

Our efforts, were, therefore, directed towards the production of a more suitable valve ; and after a time a valve with a four ampere tungsten filament and a molybdenum grid supported by electrical welding on molybdenum was produced, which led to a great improvement so far as the power obtainable and the life of the valve were concerned.

However, the inadequacy of the plate grid Lecher circuit was soon apparent ; and a new symmetrical two-valve circuit was thought out, and tried after two special valves—the mirror images of one another—had been constructed for it.

The development of this new circuit has led to the present new transmitting circuit and is shown in Fig. 1.

This new electronic oscillator is characterised by three definite tuned circuits, namely, an inside and outside filament-tuning, and a plate-tuning circuit, and also by the use of a feeder-impedance-transformer, the purpose of the latter being to match the internal resistance of the valves with that of an efficient dipole aerial.

These various circuits are indicated in Fig. 1.

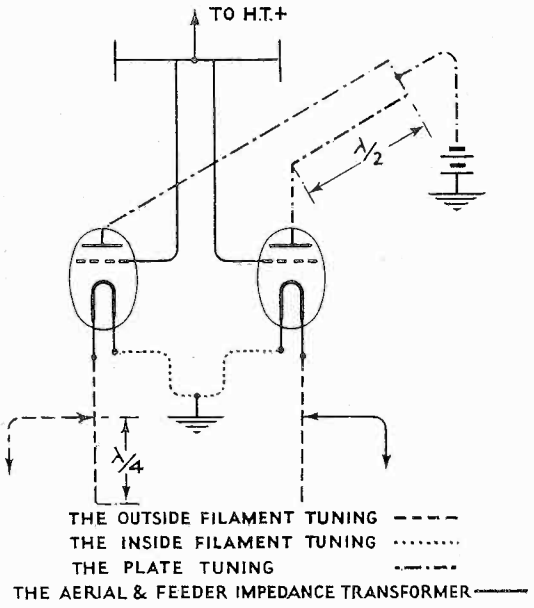


FIG. 1.

The small discs at the end of the dipole aerial are acting as end capacities and our experience has definitely indicated that their use secures more radiated power and renders easier the adjustment of the feeder-impedance-transformer than is otherwise possible.

The plate-tuning and the inside filament-tuning are the most important of all, in fact they are the controlling factors of the wavelength at which the transmitter can be made to oscillate with efficiency; all the other adjustments being dependent upon them.

It is necessary to point out that the correct length of conductor required to connect the two plates together to secure plate tuning is very small—it is only about 5 centimetres for a wavelength of the order of 50 centimetres—and the explanation of the fairly long kind of Lecher wire, shown in the above Fig. 1 is that it has been found possible and also desirable to add to that short conductor another conductor one wavelength long, bent back on itself to avoid loss by radiation.

The action of the plate-tuning is easily followed. It controls the frequency of the oscillations in a manner analogous to a straight steel bar vibrating with its middle point fixed.

This is really the case, since by connecting a thermo couple in the middle of the tuning-plate conductor and leaving the other connections free, the two plates and the conductor behave like a dipole aerial terminated by large end capacities.

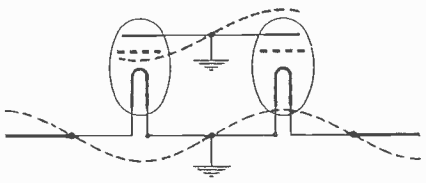
The inside and outside filament-tuning might at first appear to be acting only as effective chokes, but in fact both are necessary to ensure the correct distribution of potentials along and between the elements of the new circuit.

The correct distribution of the potential along the plate and filament circuits, obtained by these tunings, is shown in Fig. 2.

It is interesting to note that the circuit still oscillates very well—but at about half the power if the filament of one of the valves be switched out—but that the set

cannot be made to oscillate at all if one of the plates is disconnected, thus confirming again the controlling action of the plate-tunng circuit.

Of course, it is not sufficient to tune correctly all the external portions of the new circuit, it is necessary also to adjust the electrical supplies to the valves employed to generate electronic oscillations between their electrodes to a frequency corresponding as closely as possible to that to which the external circuit is tuned.



DISTRIBUTION OF POTENTIAL ALONG FILAMENT AND FILAMENT TUNING AND PLATE TUNING CIRCUIT.

FIG. 2.

There is a definite pulling effect of the oscillation into the frequency controlled by the circuit adjustments, and the closer the correspondence of the electrical adjustments to that frequency the more powerful and the more stable is the transmitter.

The degree of filament heating is another important factor upon which the efficiency of the transmitter depends. Starting with cold filaments, the oscillations will start as soon as the saturation of the grid current is reached, when the radiated energy will go on rapidly increasing as the filaments reach a further degree of brilliancy until it passes through a sharp maximum; after which a further increase in the heating of the filament will bring about a rapid decrease in the efficiency—and finally the cessation—of the oscillations.

Naturally, the development of the valves has proceeded parallel with that of the circuit.

The filament thickness of the valves, the diameter and pitch of their grids, and the length of their plates and grids were successively varied, until the best results were obtained. The method of supporting the electrodes was also investigated and found to be a matter of importance. I regret, however, that I have no time to go further into this to-night.

The radiated energy of one standard unit transmitter has been measured by placing the whole apparatus—except the aerial and feeder—in a calorimeter and taking temperature curves first with the transmitter in oscillation, and then in non-oscillating condition, all the electric currents being kept constant.

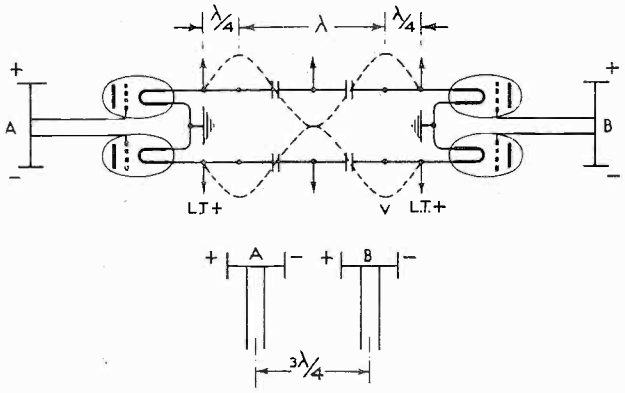
Consistent results were obtained by this method indicating an average radiation power of 3·5 watts.

The power absorbed by the filament is approximately 30 watts, that by the grid approximately 25 watts, the overall efficiency being, therefore, about 6 per cent., increasing to 14 per cent., if the grid power only be taken into account.

The possibility of substantially increasing the radiating power of a transmitter was successfully realised by running several of these unit transmitters in parallel with their aerials all in line and spaced so as to secure the maximum directive effect.

The keeping of these unit transmitters electrically in step has been rendered possible by linking up, two by two, the outside filament-tuning of adjacent transmitters by means of phasing links $1\frac{1}{2}$ wavelengths long.

Fig. 3 shows the schematic diagram of the arrangement for parallel working. It will be noticed that condensers are placed at the maximum current points, in order to permit of the independent regulation of the filament heating current of each valve; the same principle applying in the case of four transmitters.



ILLUSTRATING METHOD OF KEEPING IN STEP TWO UNIT TRANSMITTER SPACED $3\lambda/4$.

FIG. 3.

There are several ways of modulating the new transmitter. The principal methods being to superimpose the modulation of the grid high tension positive D.C. supply, or on the plate steady bias negative potential. But there are many other ways, such as push pull action on the plate or the grid, or even push pull between two transmitting units. All these methods were tried and their peculiar characteristics ascertained, but the plate modulation was adopted, at least for the time being, on account of its simplicity.

In the case of several transmitting units working in step, all the plate circuits are connected in parallel and are consequently modulated simultaneously.

The plate-filament-impedance of a unit transmitter at 1,000 cycles has been measured and found to be of the order of 2,500 ohms. This value has been successfully used for designing the modulating transformer.

(To be concluded)

MARCONI TELEVISION TRANSMITTER TYPE TT5

The T.T.5 type television transmitter modulation equipment has been designed by the Marconi Company to fill the undoubted need of television apparatus suitable for modulating high quality broadcast radio transmitters of existing type, and for producing pictures with the frequency band available of enough detail to possess entertainment attraction. With these ends in view and avoiding as far as possible any undue complication in design, the transmitter has been designed with the following constants :—

Scan lines per picture, 50.
Picture repetition frequency, 15/ *sec.*

and is described in detail in the following article :

THE television transmitter Type T.T.5 is intended for use in conjunction with a modern type of high quality broadcast radio transmitter. Three factors have been taken into consideration in the design.

(1) The television transmitter should be as simple as possible.

(2) No exorbitant demands should be made on the radio transmitter, i.e., the frequency band necessary should be within the scope of the radio transmitter and the minimum alteration to the modulation system of a high quality broadcast transmitter should be aimed at.

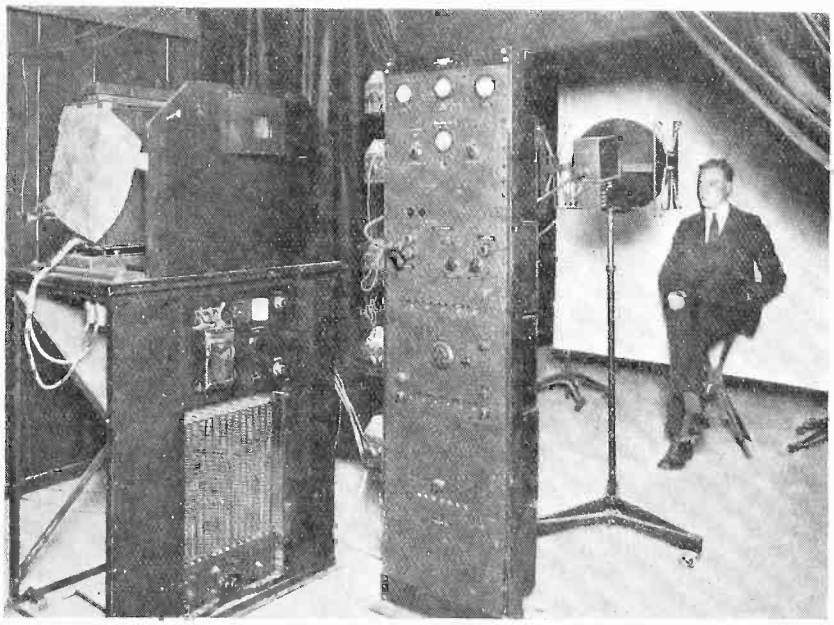
(3) The detail obtainable from the television transmitter should be as high as possible compatible with (1) and (2). It should, at any rate, be capable of giving good detail on a head and shoulders picture, and moderately good detail on a full length picture.

Bearing in mind these points, it was decided to standardise on a disc-scan type of transmitter, employing 50-scan lines per picture at a picture repetition frequency of 15. 50-scan lines were chosen as it was felt that this was the minimum necessary to give enough detail, and any increase on 50 lines would involve too wide a frequency band for the standard broadcast transmitter. The picture repetition frequency of 15 was chosen as the lowest which produced inappreciable flicker.

The theoretical maximum frequency necessary for this type of transmitter is $\frac{50 \times 50 \times 15}{2}$ or 18,750 cycles. It has been found in practice, however, that a good picture can be transmitted with a maximum frequency of just over 13,000 cycles, and since most modern broadcast transmitters have a reasonably constant frequency response up to frequencies in this neighbourhood, such a transmitter should be capable of radiating moderately good television signals.

The disc type of scan was chosen as it represents undoubtedly the simplest method of scanning, and produces good results with the minimum expense.

Finally, a square scan frame was chosen (i.e., the picture which can be transmitted is square), as it was felt that this represented the best compromise of picture shape for both head and shoulders and full length scans. Horizontal scanning is employed as this produces less flicker than the use of a vertical scan.



Television Modulating Equipment, Type T.T.5.

Scanning.

The method known as indirect scanning has been employed in this transmitter. This method consists of causing a rectangular spot of light of constant intensity to traverse the subject being televised in a series of contiguous nearly straight lines. This process is called scanning, and one complete traversal of the subject is termed a scan. In order to represent motion at the receiver, it is necessary to scan the subject many times each second, for if more than ten complete images are reproduced per second, the observer's eye is not able to separate one image from the next and sees them as one continuous image.

The light reflected from the subject during scanning is picked up by a photocell which converts the varying light densities into currents of varying amplitudes and it is this modulated current which is first amplified and then caused to modulate the radio transmitter.

It is obvious that the greater number of scan lines per scan area the more picture detail will be transmitted, for each part of the picture will be scanned in more detail. It is not necessary here, however, to enter into a discussion of the difficulties involved in increasing picture detail. Suffice it to say that when 50 scan lines are employed per scan, the detail of the picture is sufficiently good to enable recognisable head and shoulders and even full length images to be received.

Any further increase in the number of scan lines as has been stated above, would lead to an appreciable increase in the bulk of the apparatus, and the radio transmitter would have to be of special design.

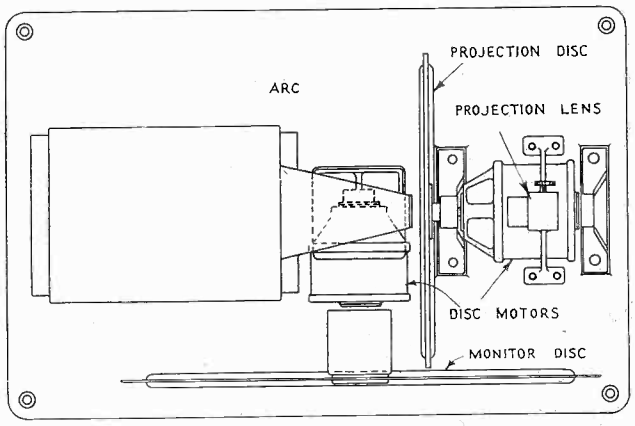


FIG. 1. *Layout of Scanning Head.*

Scanning System.

This apparatus comprises, excluding power equipment, five major units, scanning head, modulation bay, mobile photo-cell amplifiers and an adjustable screen.

Each major unit will be described separately and in detail.

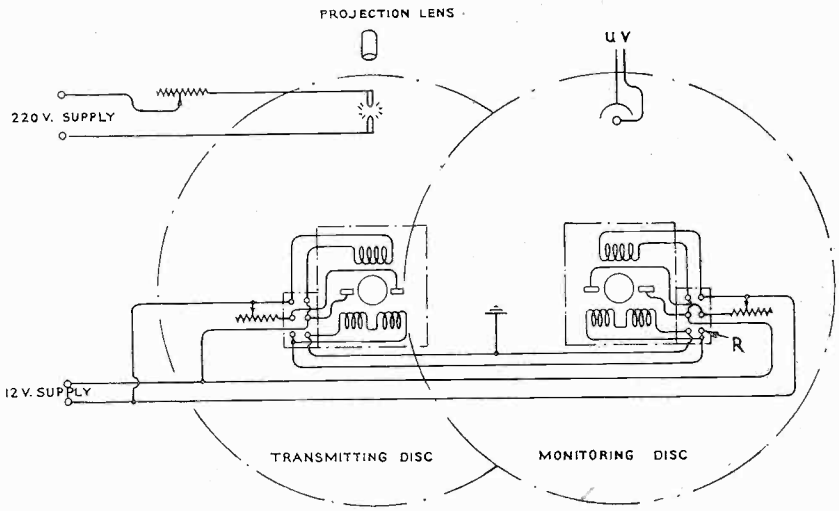


FIG. 2. *Diagram of Connections, Scanning Head.*

Scanning Head.

This consists of a rectangular iron framework on the top of which is bolted an aluminium casting carrying the arc and scanning apparatus. On one vertical face of the framework is fixed a variable resistance and a small control board.

Scanning Apparatus.

This comprises two Nipkow discs, a motor for driving the discs, two projection lenses and an arc lamp. (Figs. 1 and 2.)

The transmitting disc proper is constructed of 24 gauge aluminium sheet which is punched with 50 square holes ·45 mm. in size. These holes or apertures are arranged round the disc in the form of a spiral and are spaced at 7·2° apart, each

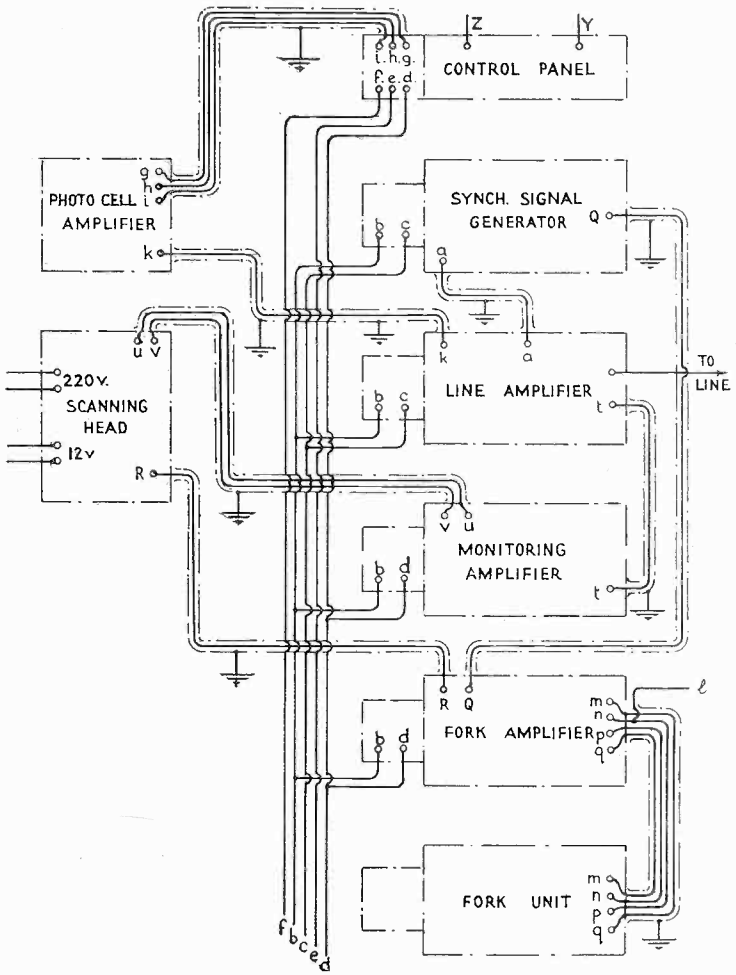


FIG. 3. *Schematic Diagram of Modulation Equipment.*

hole being nearer (or further away, depending on which direction the spiral is followed) to the centre of the disc by exactly its own width (19 cm. outside spiral radius). This disc is screwed to a thicker aluminium disc in which holes are drilled to clear the apertures in the thinner disc. This is done for the purpose of stiffening, and steadiness in running. The disc is driven directly from an $\frac{1}{8}$ H.P. synchronous motor which is driven from a D.C. supply of 12 volts and maintained at a constant

rate of revolutions by a separate A.C. supply. This will be further described later. At right angles to the transmitting disc is a second disc which is used for the purpose of " monitoring " the transmitted picture. This is driven by a second motor which is fitted with both A.C. and D.C. windings, and is kept revolving in synchronism with the transmitting disc motor by being run back to back with the latter, the object of this being to avoid the trouble of synchronising the monitor with the transmitter.

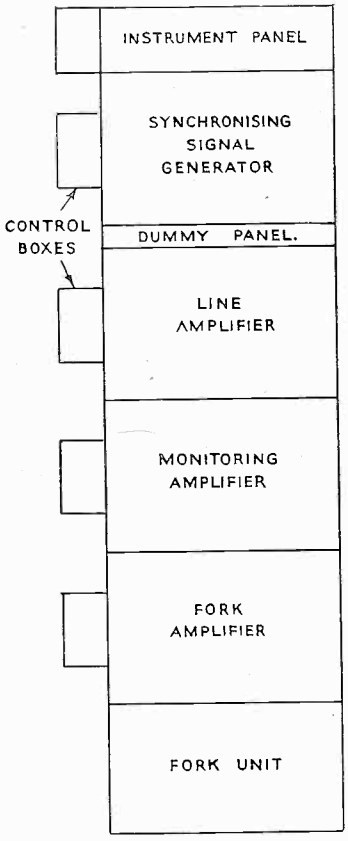


FIG. 4.
Layout of Modulation Bay.

The arc lamp is " hand fed " and is equipped with an hemispherical reflecting mirror. It is situated directly behind the disc and projects a beam of light on to the top vertical centre of the disc, forming an illuminated area sufficient to embrace 22·5 mm.□ corresponding to a 7·2° arc which forms one picture. The holes in the disc pass through this illuminated area and the light passing through the holes is thrown on a screen through one of the two lenses the apertures in the disc being focused on to the subject which is placed in front of the screen and in the light beam. Two alternative lenses are provided for use when scanning a full length figure or when a close-up of a head is being transmitted.

FIG. 5. *Photo-cell Unit.*

The telephoto lens which is used for close-up head and shoulder scanning has a focal length of 9 in. and an aperture of 4·5 gives a highly magnified image at great distance, and enables an extremely small scan area to be projected at a greater distance than the normal projection lens, thus the subject can be moved much farther away from the scanning disc and light source ; a condition which gives much more space for the manipulation of any photo cell system, and which provides a great depth of focus, so that the subject may move backward or forward some four feet without being effectively out of focus.

An iris diaphragm is used as a control of the amount of scan light falling on the subject thus providing an excellent " volume control " and eliminating such devices in the amplifier system which are always sources of frequency loss, noises, and such like.

The telephoto lens is mounted in front of the disc and is fixed to a sliding telescopic tube for focusing purposes. The iris diaphragm is controlled by a simple Bowden attachment, the lever of which is fixed in a convenient position on the scan table.

The full length lens has a focus of 2 in. and aperture of 1·8, and is used to scan an area of about 6 feet square at a distance of 14 feet from the transmitter.

The lenses are mounted on arms and are selected by a simple swing-over device. An adjustable frame is fixed between the disc and the lens for the purpose of adjusting the length of traverse of the light spot so that the end of one scan is immediately followed by another.

The monitor disc is larger in size than the transmitter disc, the dimensions being : apertures ·75 mm., outside spiral radius 33 cm., this being used for the purpose of check reception is equipped with a neon tube having a flat plate some 4 cm. This is placed behind the disc and vertically above the disc spindles. This plate when luminous lights up an area of the disc corresponding to one picture area. A viewing lens and holder is mounted in front of the disc, for the purpose of magnifying the image and cutting out extraneous light.

The power taken by the arc is controlled by the variable resistance in the front of the stand. The control board contains the arc supply switch, motor supply switch, motor regulator, motor supply fuse, plug socket for purpose of checking motor supply volts and two plug sockets for A.C. supply to motor and supply to neon lamp.

The light reflected from the scanned subject is converted into electrical impulses by means of a photo cell and these are amplified to a degree suitable for modulating a radio transmitter in :

(A) the photo cell amplifier ;
(B) the line amplifier.

The photo cell is placed at the focus of a spherical mirror, and the reflector, photo cell and amplifier are mounted together as one unit and are attached by means of four strands of aeroplane elastic to a stand having three castors. The stand has a telescopic rod by means of which the unit may be adjusted for height or swivelled into the desired position. A photograph of the unit is given in Fig. 5, and diagrams of connections and layout in Figs. 6 and 7.

The reflector consists of a silvered concave mirror 14 inches in diameter and having a focal length of $4\frac{1}{2}$ inches. This has an effective pick-up of 2 square feet at about 14 feet from the face of the reflector.

The reflector is mounted in a cone-shaped framework at the apex of which is screwed a hollow threaded brass tube. This tube projects through a hole in the centre of the reflector, and at that end is provided with two clamps for holding a photo cell. The other end of the tube is screwed into a bracket on the amplifier which is sufficiently strong to support the weight of the reflector and its housing. Thus, when the reflector case is turned bodily, the position of the photo cell is varied along the optical axis of the reflector, thus providing an adjustment of pick-up area. The two connecting leads from cell to valve are brought through the tube providing

as short a path and as well screened an arrangement as is necessary at the present stage of progress. The front of the reflector is fitted with a brass wire screen of

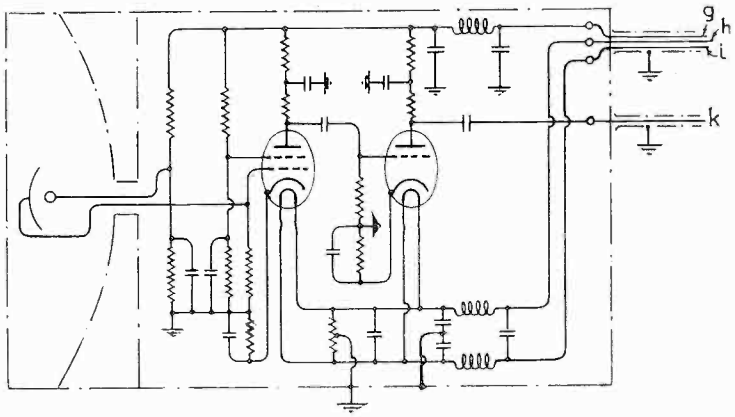


FIG. 6. *Diagram of Connections, Photo-cell and Photo-cell Amplifier.*

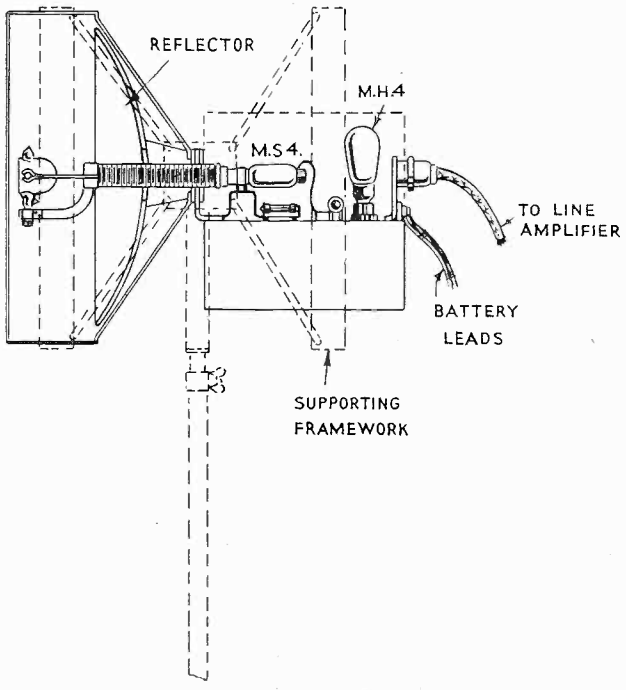


FIG. 7. *Layout of Photo-cell Unit.*

$\frac{1}{4}$ inch mesh. This is necessary for complete stability and does not drop the amount of pick-up to any appreciable extent.

The amplifier is designed so that the first valve is positioned as near the photo-cell as possible avoiding higher frequency loss and assisting in stability and freedom from radio frequency pick-up.

Indirectly heated valves are used because microphonics are less, and also, the bias for photo cell and grids of valves and anode and screen grid potentials can be obtained from one 400-volt battery. This avoids the use of numbers of dry cells which are always sources of trouble and also allows a very compact arrangement to be devised which is entirely free from radio frequency pick-up.

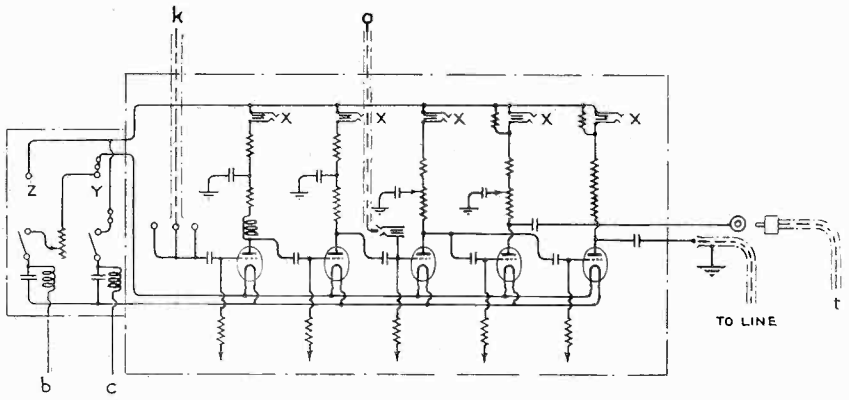


FIG. 8. *Diagram of Connections, Line Amplifier.*

The amplifier comprises two valves, the first being an M.S.4 and the second an M.L.4 or an M.H.L.4. All decoupling and potential dividing resistances and blocking condensers are mounted under the base. On the base are mounted the two valves, anode resistances, condensers and grid leaks. The covers and base are made of duralumin and the top cover is lined with felt to prevent microphonics.

Line Amplifier.

The output from the photo cell amplifier is taken by means of a completely screened flexible lead to the input of the line amplifier which serves to raise the television signals to a suitable level for transmission over a landline to the modulation section of the ratio transmitter. This amplifier consists of 4 stages of resistance-capacity coupled amplification and is of orthodox form with the exception that special means are taken to prevent high frequency cut off and to obtain an approximately equal frequency response up to 18,000 cycles. The diagram of connections of this amplifier is given in Fig. 8. The amplifier is mounted in a rack together with the control panel, monitoring amplifier and synchronising apparatus. The amplifier is completely screened and great care has been taken in the preliminary stages to protect the valves from mechanical vibration in order to avoid microphonic effects which if present, would completely ruin the picture. It will be seen on reference to the figure that the grid circuits of the fourth and fifth valves are paralleled off from the anode circuit of the third valve by means of condensers. The output to the line is taken from the anode circuit of the fifth valve through a condenser and terminating resistance the value of which is adjusted to suit the constants of the line. The output from the fourth valve is tapped through a condenser

and input to the L.F. side of the monitoring amplifier, the output of which feeds the monitoring neon tube thus providing a ready means for checking the picture which is being sent out by the television transmitter. This will be referred to later.

Means are provided in the line amplifier for reading all voltages and feeds. Gain control is supplied for the amplifier as a whole and for the monitoring valves separately.

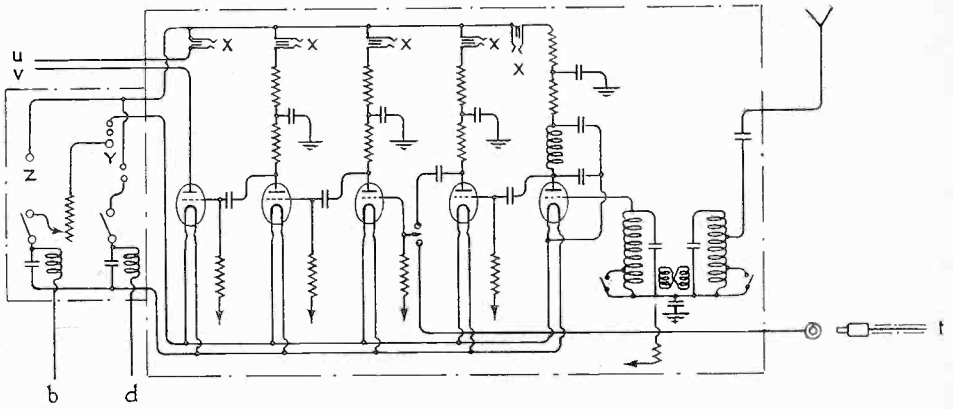


FIG. 9. *Diagram of Connections, Monitoring Amplifier.*

Monitoring Amplifier.

The monitoring amplifier (Fig. 9) consists of a complete receiver composed of a radio frequency circuit consisting of a band pass filter and anode bend detector, followed by four resistance-capacity coupled L.F. stages and is constructed in such a way that the picture being sent out from the television transmitter can be checked either

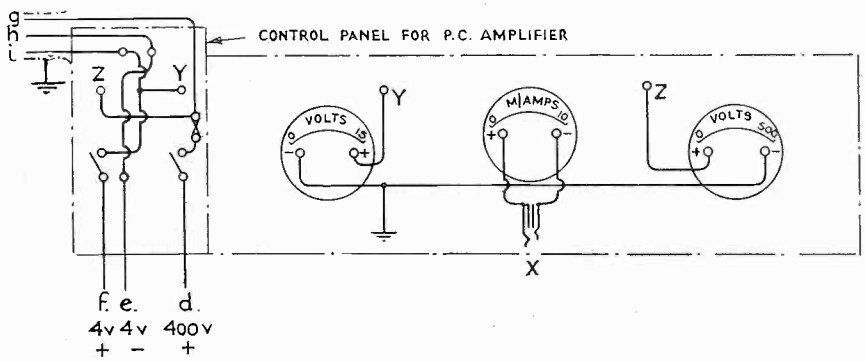


FIG. 10. *Control Panel.*

before modulating the radio transmitter or after passing through the radio transmitter. If it is desired to check the picture actually transmitted from the radio transmitter, the complete monitoring amplifier is made use of and a small aerial picks up the radiated signal, passes it through the band pass filter to the detector of the monitoring amplifier and on to four stages of low frequency magnification.

The neon tube is connected directly in series with the anode circuit of the last valve and is scanned by means of the monitoring disc mentioned on page 12. If it is desired to check the local signal being generated by the television transmitter, the output from the fourth valve of the line amplifier is coupled by means of a capacity to the second stage of the L.F. side of the monitoring amplifier, after which it is passed to the monitoring neon tube. Provision is made for change from one method to the other to be effected by means of a switch. In this way either the line or radio signal may be observed in the monitor neon tube.

Control Panel.

The control panel (Fig. 10) carries the following instruments :—A voltmeter 0—12 for reading L.T. supply, voltmeter 0—500 for reading H.T. supply, and milliammeter 0—10 for reading feeds to the valves, the jack switches in valves giving high feed being shunted to give 10 ma. In addition to this control panel, small control boxes are mounted by the side of the line amplifier, monitoring amplifier, fork amplifier and synchronising signal generator, which contain the fuses for these units and also such local controls as are needed. In these boxes there is also sufficient space for any H.F. chokes, by-pass condensers which may be needed to exclude H.F. from the amplifiers when the apparatus is installed near the radio transmitter.

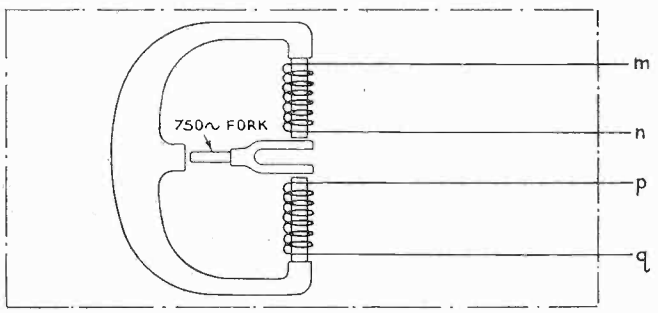


FIG. 11. *Fork Unit.*

Synchronising.

As the rest of the apparatus of the transmitter is concerned with the synchronisation of the transmitter discs and the receiver mechanism, it will be advantageous here to describe exactly what is meant by synchronisation and to discuss the means utilised for providing it in this type of television transmitter. In any method of television involving at the transmitter end the analysis of a picture by means of scanning, the problem of synchronisation is, in its most general sense, the problem of arranging that at any given instant, that part of the picture being reproduced at the receiving end bears the same spatial relation to the scanned area as the part of the receiver being scanned at the transmitting end bears to the scanned area at the transmitter end.

In a system involving scanning by rotating drums, mirror wheels, or discs, this problem resolves itself into keeping the receiver mechanism rotating at the

same speed as the transmitter mechanism. Therefore, the chief requirements of any synchronising system are that :—

(1) The system should be capable of running the receiving system at an identical speed to that of the transmitting system.

(2) The system should be capable of correctly framing the picture at the receiving end.

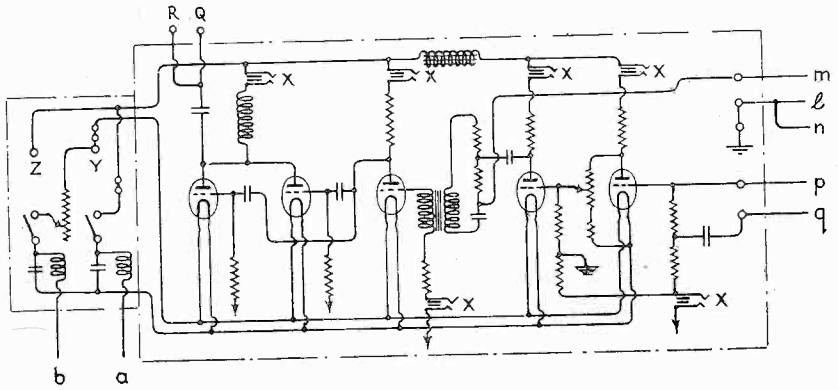


FIG. 12. *Diagram of Connections, Fork Amplifier.*

By the expression "correctly framing" we mean that the received picture bears the same relation to the received scanning area as the transmitted picture bears to the transmitting scanned area. In other words, conditions (1) and (2) mean that (1) correct speed and (2) correct phase shall be maintained. If identity of speed is satisfied without identity of phase, the received picture although stationary may be translated in the received scanned area either horizontally or vertically, or both.

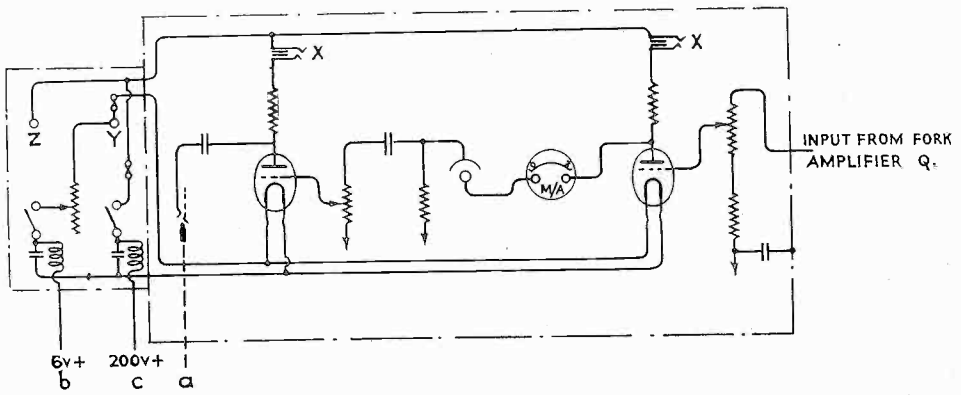


FIG. 13. *Diagram of Connections, Synchronising Signal Generator.*

The simplest method of satisfying the above conditions is to transmit an impulse at the end of each scan line signal, which impulse serves to keep the receiving mechanism rotating at an identical speed to that of the transmitting mechanism and

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also insures automatically correct phase relations. In order that too stringent demands may not be made on the rotating receiving mechanism, it is essential that means should be provided for keeping the transmitter mechanism rotating at as constant a speed as is possible.

Coming now to the actual design of the synchronising system employed on the T.T.5 television transmitter, we see that we have to provide firstly, a constant speed control for the transmitting disc motor, and secondly, mechanism for injecting the synchronising impulse at the end of each scan line.

The transmitting disc motor is maintained at a constant speed by means of a fork, electrically driven, mounted in the bottom panel of the rack. Immediately above this is mounted an amplifier which serves to amplify the fork impulses to such a level that when they are applied to the A.C. winding of the transmitting disc motor they serve to keep this motor revolving at a constant speed. Diagrams of connections of the fork unit and fork amplifier are given in Figs. 11 and 12, and no further description need be given here. The method of producing the synchronising impulses, injecting them into the television signals at a correct time, and at the receiving end separating these signals from the received television signals and applying them to synchronise the receiving disc motor, is fully protected by patents and is described hereunder.

At the transmitter end the fork signal which is applied to the synchronising winding of the transmitting disc motor is also applied as shown in Fig. 13, to the grid circuit of the first valve contained in the synchronising signal generator which is mounted in the top panel but one of the amplifier rack. This valve is coupled to a second valve by means of a neon tube and condenser and the output from the second valve is taken after one more stage of amplification to the third valve of the line amplifier and there injected into the television signal, being amplified in this latter amplifier, a synchronising impulse at the end of each scan line. Neon tube coupling is used between the first and second valves of the synchronising signal generator in order that it may pass on to the further stages of this generator short sharp impulses of greater amplitude than the television signals.

At the receiver end a similar neon tube coupled stage serves to separate the higher amplitude synchronising signals from the television signals, the former of which are passed to the light valve and the latter to the synchronising winding of the receiver motor.

A schematic diagram and layout diagram of the modulation equipment are given in Figs. 3 and 4, which make the method of interconnection of the various units quite clear.

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TY OF
ARCONI CO.

THE INTERFERENCE PATTERN OF THREE CARRIER WAVES

A proposal was put forward to run three separate transmitters each radiating the same intelligence, telephonic speech, and having a frequency separation of about 7 kc. The radiation from any or all of the three transmitters was to be picked up by receivers whose frequency response is wide enough to receive them all at the same time. The problem is novel, and contains a number of interesting points. It is clear that if the three transmitters each maintain their exact frequency separation the beat envelope from the carriers will be outside the speech frequency band, but evidence is required as to whether any deleterious interference pattern will be formed by the drifting of the individual carrier waves from their correct setting. The problem will be examined first by a mathematical analysis, and secondly by a graphical and experimental method, and finally a general résumé of the results of the investigation will be given.

PART I.

Qualitative Mathematical Analysis.

THE following mathematical analysis is an approximate qualitative representation of the heterodyne envelope of three sine waves having particular reference to three high frequency sine waves. The general case of unequal amplitudes and random frequencies is taken but in practice the interesting case is for waves differing in frequency by frequencies lying in the audible band.

Let the three sine waves be considered as e.m.f. waveforms and let them be represented as follows :—

$$E_1 = \hat{E}_1 \sin \omega_1 t$$
$$E_2 = \hat{E}_2 \sin \omega_2 t$$
$$E_3 = \hat{E}_3 \sin \omega_3 t$$

Since we are considering the envelope of the combination, it is the variation in the maximum values of the resultant e.m.f. (E) which will give us most information.

With reference to Fig. 1, the following expression for the maximum e.m.f. may be derived.

$$\hat{E} = \sqrt{\{\hat{E}_3 \sin(\omega_3-\omega_1)t + \hat{E}_2 \sin(\omega_2-\omega_1)t\}^2 + \{\hat{E}_1 \cos(\omega_1-\omega_2)t + \hat{E}_3 \cos(\omega_3-\omega_1)t\}^2}$$

$$\hat{E} = \sqrt{\begin{array}{l}\hat{E}^2_3 \sin^2(\omega_3-\omega_1)t + \hat{E}^2_2 \sin^2(\omega_2-\omega_1)t + 2\hat{E}_3\hat{E}_2 \sin(\omega_3-\omega_1)t \sin(\omega_2-\omega_1)t \\ + \hat{E}^2_1 + \hat{E}^2_2 \cos^2(\omega_1-\omega_2)t + 2\hat{E}_1\hat{E}_2 \cos(\omega_1-\omega_2)t + \hat{E}^2_3 \cos^2(\omega_3-\omega_1)t \\ + 2\hat{E}_1\hat{E}_3 \cos(\omega_3-\omega_1)t + 2\hat{E}_2\hat{E}_3 \cos(\omega_1-\omega_2)t \cos(\omega_3-\omega_1)t.\end{array}}$$

$$= \sqrt{\begin{array}{l}\hat{E}^2_1 + \hat{E}^2_2 + \hat{E}^2_3 + 2\hat{E}_1\hat{E}_2 \cos(\omega_1-\omega_2)t + 2\hat{E}_1\hat{E}_3 \cos(\omega_3-\omega_1)t. \\ + 2\hat{E}_3\hat{E}_2 \{\cos(\omega_1-\omega_2)t \cos(\omega_3-\omega_1)t + \sin(\omega_3-\omega_1)t \sin(\omega_2-\omega_1)t.\}\end{array}}$$

$$= \sqrt{\hat{E}^2_1 + \hat{E}^2_2 + \hat{E}^2_3 + \Sigma\, 2\hat{E}_1\hat{E}_2 \cos(\omega_1-\omega_2)t.}$$

$$= \{\hat{E}^2_1 + \hat{E}^2_2 + \hat{E}^2_3 + \Sigma\, 2\hat{E}_1\hat{E}_2 \cos(\omega_1-\omega_2)t\}^{\frac{1}{2}}$$

The expansion of this expression is an infinite series and it is not proposed to consider the expansion in detail, a diminishing one, in this approximate analysis.

It is clear however that the three fundamental frequencies present in the envelope are $(\omega_1-\omega_2)$, $(\omega_2-\omega_3)$, and $(\omega_3-\omega_1)$.

It is also clear that these frequencies have not sinusoidal waveforms, but have harmonics present whose magnitudes are dependent upon the relative magnitudes of the three original sine waves.

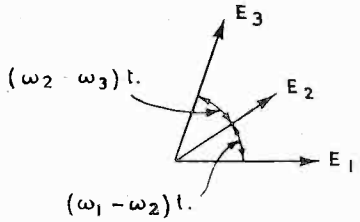


FIG. 1.

In addition to the above consideration of the envelope, a complete survey of the system would involve a consideration of the resultant radio frequency waveform. Since we are more directly concerned with the waveform after rectification and since the radio frequency components will be removed during the rectification process, it is not proposed to give the analysis, but it may be noted that a degree of frequency modulation of the radio frequency component will be experienced.

After rectification we shall have the three fundamental frequencies $(\omega_1-\omega_2)$, $(\omega_2-\omega_3)$, and $(\omega_3-\omega_1)$ existing independently, and they will then beat with each other. If we write these three frequencies in order as ω_4, ω_5, ω_6, and express the waveforms as :—

$$E_4 = \hat{E}_4 \sin \omega_4 t$$
$$E_5 = \hat{E}_5 \sin \omega_5 t$$
$$E_6 = \hat{E}_6 \sin \omega_6 t$$

we shall have a similar set of terms to those for the original radio frequency sine waves.

(N.B.—This neglects all harmonics produced in the radio frequency envelope).

By analogy from the previous analysis we shall have the terms $(\omega_4-\omega_5)$, $(\omega_5-\omega_6)$, and $(\omega_6-\omega_4)$, in the resultant low frequency envelope.

This is not all, however, for in this case we must consider the actual fundamental waveform as well as the envelope, since both are in the audio frequency band.

We shall have for the fundamental waveform the expression :—

$$\hat{E}_4 \sin \omega_4 t + \hat{E}_5 \sin \omega_5 t + \hat{E}_6 \sin \omega_6 t.$$

$$= \tfrac{1}{4} \Sigma \{(\hat{E}_4-\hat{E}_5)(\sin \omega_4 t - \sin \omega_5 t) + (\hat{E}_4 + \hat{E}_5)(\sin \omega_4 t + \sin \omega_5 t)\}$$

$$= \tfrac{1}{2} \Sigma \left\{(\hat{E}_4-\hat{E}_5)\left(\sin\left(\frac{\omega_4-\omega_5}{2}\right)t \cos\left(\frac{\omega_4+\omega_5}{2}\right)t + (\hat{E}_4+\hat{E}_5)\left(\sin\left(\frac{\omega_4+\omega_5}{2}\right)\cos\left(\frac{\omega_4-\omega_5}{2}\right)t\right\}\right.$$

$$= \tfrac{1}{2}\left(\sin\left\{\left(\frac{\omega_4+\omega_5}{2}\right)t + \Psi\right\} + \sin\left\{\left(\frac{\omega_5+\omega_6}{2}\right)t + \rho\right\} + \sin\left\{\left(\frac{\omega_6+\omega_4}{2}\right) + \beta\right\}\right)$$

where $\Psi = \tan^{-1} \dfrac{\hat{E}_4-\hat{E}_5}{\hat{E}_4+\hat{E}_5} \tan\left(\dfrac{\omega_1-\omega_2}{2}\right)t$,

and ρ and β are similar expressions.

We thus have frequencies $\left(\frac{\omega_4+\omega_5}{2}\right)$, $\left(\frac{\omega_5+\omega_6}{2}\right)$ and $\left(\frac{\omega_5+\omega_4}{2}\right)$

Also the presence of the components Ψ, ρ and β implies a certain amount of frequency modulation at frequencies $\frac{\omega_4-\omega_5}{2}$, $\frac{\omega_5-\omega_6}{2}$, $\frac{\omega_6-\omega_4}{2}$ and whose degree is controlled by the relative magnitudes of $\hat{E}_4$, $\hat{E}_5$, and $\hat{E}_6$, and hence of $\hat{E}_1$, $\hat{E}_2$, and $\hat{E}_3$. (These frequencies will be produced to some extent apart from frequency modulation, for the fundamental radio frequency waveform will contain terms of frequencies $\frac{\omega_1+\omega_3}{2}$, $\frac{\omega_2+\omega_3}{2}$, and $\frac{\omega_3+\omega_1}{2}$ whose differences are $\frac{\omega_4-\omega_5}{2}$, $\frac{\omega_5-\omega_6}{2}$, and $\frac{\omega_6-\omega_4}{2}$.)

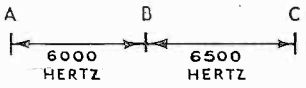


FIG. 2.

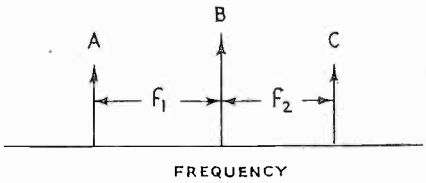


FIG. 3.

To illustrate the practical implications of this analysis take the following two cases :—

(A) *Three Radio Frequencies of Slightly Differing Separations.*

Consider the three radio frequencies A, B and C, in Fig. 2. After rectification the following frequencies together with their harmonics will be present.

250, 500, 3,000, 3,250, 3,500, 6,000, 6,250, 6,500 and 12,500 hertz. Of these frequencies 6,000, 6,500, 12,500 and 500 hertz will be by far the most prominent and 250 will be small.

(B) *Three Radio Frequencies, one of which is continuously varied so that initially equal separations are altered to the ratio of* 2 : 1.

Consider the three radio frequencies A, B and C, of Fig. 3, the separation of A and B being kept at 2,000 hertz and B and C varying continuously from 2,000 to 4,000 hertz. After rectification the following frequencies will be present. The most prominent are marked by an asterik.

Initial. 0, 1,000, 1,000, 0*, 2,000*, 2,000, 2,000*, 3,000, 3,000, 4,000*.
Final. 1,000, 1,000, 2,000, 2,000, 2,000, 3,000, 4,000, 4,000, 5,000, 6,000.

or more briefly

Initial. 0*, 1,000, 2,000*, 3,000, 4,000*.
Final. 1,000, 2,000* 3,000, 4,000*, 5,000, 6,000*.

The relative magnitudes of these frequencies will, of course, be dependent upon the relative magnitudes of the original sine waves. For example, if the centre sine wave is large compared with the other two, then the expressions $2\hat{E}_1\hat{E}_2 \cos(\omega_1-\omega_2)t$ and $2\hat{E}_2\hat{E}_3 \cos(\omega_2-\omega_3)t$ will predominate over $2\hat{E}_3\hat{E}_1 \cos(\omega_1-\omega_2)t$. In the case (A) above this implies first of all that the frequencies 6,000 and 6,500 hertz will predominate over the 12,500 hertz. Also their difference frequency, 500 hertz, will be greater than the other two difference frequencies. Also since $\hat{E}_2 > \hat{E}_1\ \hat{E}_3$ and if $\hat{E}_1$ is approximately equal to $\hat{E}_3$, it follows that the 500 hertz frequency will predominate over the 6,000 and 6,500 hertz frequencies.

In conclusion it may be said that the above analysis while dealing only very approximately with a comparatively complicated subject, yet gives a fairly wide indication of the effects that may be experienced in practice.

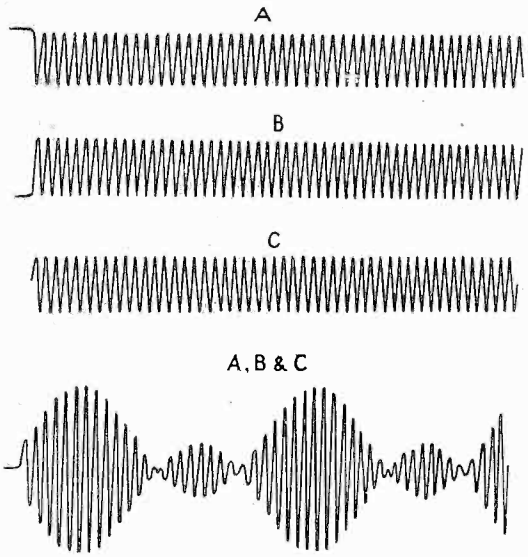


FIG. 4.

PART II.

Graphical Investigation of the Beating of Three Waves having equal or nearly equal separation.

To investigate the problem fully it is clear that we must consider different conditions both of amplitude and relative frequency of the three carriers. If we assume three radio carrier waves, A, B and C, Fig. 3, separated by frequency intervals f_1 and f_2, we require to find the interference pattern under the following conditions :—

1. Amplitudes A, B and C, all equal.
   - (*a*) With frequency separation $f_1 = f_2$ and different relative phases.
   - (*b*) With frequency separation $f_1 \gtrless f_2$.
2. Amplitude of centre frequency B greater than A and C.
   - (*a*) With frequency separation $f_1 = f_2$ and different relative phases.
   - (*b*) With frequency separation $f_1 \gtrless f_2$.
3. Amplitude of one side wave A or C greater than B or other side wave.
   - (*a*) With frequency separation $f_1 = f_2$ and different relative phases.
   - (*b*) With frequency separation $f_1 \gtrless f_2$.

1. *Amplitudes all equal.*
   - (*a*) *With frequency separation* $f_1 = f_2 = f_b$ *say.*

The general form of vave is one of frequency of carrier B, varying in amplitude at a frequency of $2\,f_b$ unevenly, shown in Fig. 4. This unevenness is because the envelope is comprised of two frequencies each of f_b asymmetrically but equally disposed one on either side of the datum line.

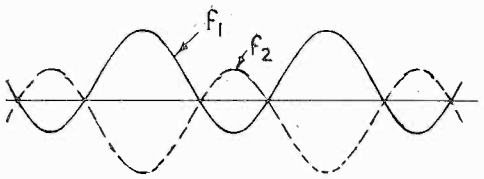


FIG. 5.

We can show this more clearly by Fig. 5, where f_1 and f_2 are the two equal envelope frequencies interlinked, the effect after rectification being the asymmetrical frequency $2\,f_b$.

This envelope will be obtained only if the phase of the centre frequency is relatively mid-way between the two extreme frequencies as in an ordinary modulation envelope.

If the phase is moved to a value in quadrature the effect is as shown in Fig. 6, namely, the two frequencies f_1 f_2 are now moved to be symmetrically disposed on the datum line, this condition being depicted more clearly in Fig. 7, which assumes no frequency change.

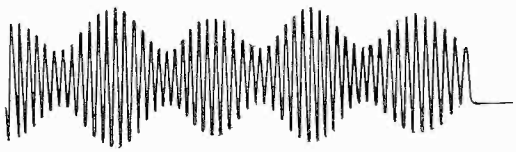


FIG. 6.

In addition to the amplitude change of envelope there will also be found to have been introduced a frequency modulation of $\frac{f_b}{2}$, the limits of this frequency wobble being very small, and depending upon the relative amplitudes of the three waves. The effect of the frequency modulation is to demodulate the amplitude change as can be seen by comparing Figs. 6 and 7. There are, of course, intermediate conditions of this effect, one of which is shown in Fig. 8, which give a relative phase shift of 45° of the centre frequency.

It is interesting to note that the change of relative phase of the centre frequency does not shift the envelope frequencies in time relative to one another, but merely moves them towards or away from the datum line. Thus if the separation frequency of each carrier is 7 kc. the general form of envelope will be one of 14,000 kc. but having a strong 7 kc. component, the relative amplitude varying with phase change of the waves.

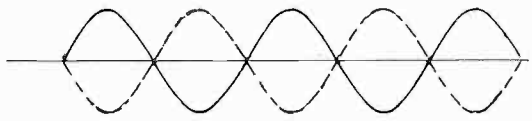


FIG. 7.

(B) *Frequency separation* $f_1 \gtrless f_2$.

If one frequency is made slightly greater or less than the other, the high frequency wave is changing in frequency periodically and two envelope frequencies are now present f_1 and f_2, interlinked, but changing their relative positions cyclicly on the datum line.

The rectified envelope is thus made up of the two separation frequencies varying cyclicly in amplitude and beating together as shown in Fig. 9, simplified in Fig. 10, and this cyclic change is a frequency $f_d = (f_1 - f_2)$ or $(f_2 - f_1)$.

FIG. 8.

The waveform produced is clearly similar to the case (1) with different phase shifts, namely, each wave envelope is being moved relative to the time base, but since there is a gradual change of amplitude of each wave at a low frequency, this low frequency beat, if within the audible range will appear as a note because of the receiver rectifier. Since this beat will be produced with a very small percentage frequency drift of the original high frequency waves, it is this frequency which is of the greatest importance. For instance if frequency A is 7,000 cycles below frequency B, and frequency C, 7,250 above, in addition to frequencies 7,000, 7,250, 14,000, 14,500, we shall have a frequency of 250 cycles appearing as well, which will be most serious.

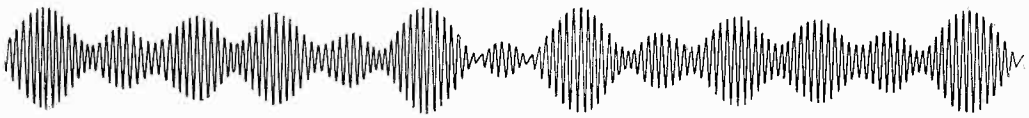


FIG. 9.

(2) *Amplitude of middle wave greater than A or C, and greater than the sum of A and C.*

(A) *With equal separation of frequencies* $f_1 = f_2 = f_b$.

In the special circumstances of the phase being correct, the double envelope frequency 2 f_b may now completely disappear and a frequency of f_b becomes prominent, as shown in Fig. 11. This is only so if the amplitude of B is equal or greater

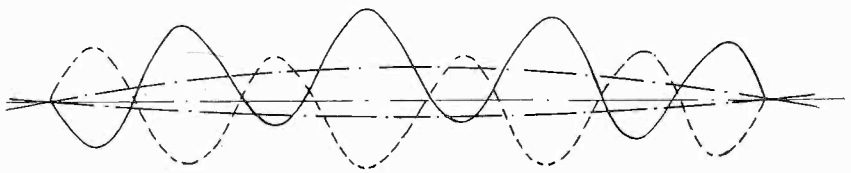


FIG. 10.

than the sum of A and C. In this condition the series are exactly analogous to a carrier modulated by a frequency of f_b. If the phase is shifted the frequency f_b will tend to disappear, but harmonic frequencies of f_b will appear and the demodulation of the main frequency will be accompanied by the introduction of a frequency modulation, and this frequency modulation and distortion will diminish as the amplitude of the centre wave increases.

(B) *With unequal frequency separation.*

When there is unequal frequency separation there will be as in case 1 (B) a cyclic change of envelope having a small frequency modulation. As before, this cyclic envelope change is really made up of the two separation frequencies beating together, and the difference of these separation frequencies will appear as an interference beat, should its value lie in the audible range. But since the separation frequency (and not twice) component is now stronger than before the beat frequency will tend to increase in amplitude.

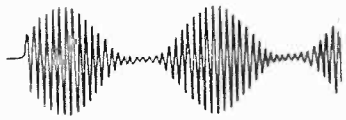


FIG. 11.

(3) *Amplitudes of one side wave say C greater than A or B.*

(A) *With equal and unequal separation.*

In general a similar form of envelope will be obtained as in the case 1, except the double frequency envelope is more in evidence, the frequency modulation introduced is much greater and in consequence the envelope is discontinuous, Fig. 12 showing one example with $f_1 = f_2$ and 90° phase shift of B.

PART III.

Vector Analysis.

Mention was made of the demodulation effect of phase shift and the introduction of frequency modulation. Exactly how this comes about can best be seen by vector analysis. Let us consider first the case of three carriers of equal amplitude and equal spacing, that is, we have to think of the addition of three rotating vectors, A, B and C, as shown in Fig. 13.

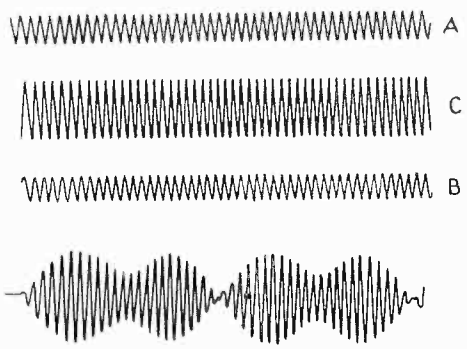


FIG. 12.

Now since at all moments vector C is gaining on vector B as much as vector A is losing, we can for convenience consider vector B stationary, and vectors A and C rotating, the vector C in an anti-clockwise direction, and vector A in a clockwise direction at the same rate, namely, that of the frequency separation.

Now since the frequency separation is the same, the vector resulting from vectors A and C will always be exactly in phase or in phase opposition to vector B, but will vary in amplitude from a vector twice the amplitude of vector B and in phase (when vectors A and C are in quadrature with vector B, but in phase opposition to each other) to a vector twice the amplitude of vector B but in phase opposition. This cyclic variation of the resultant of vectors A and C together with vector B produces a vector V_R which is always in line with vector B, but varies in amplitude from three times the amplitude of vector B to a vector the amplitude of vector B in phase opposition. The cyclic change of the vectors is shown in Fig. 12, at various angles as indicated. Since this vector group is rotating at a constant speed of

vector B it is clear that the resulting wave is one of constant frequency, that of B, but changing in amplitude at twice the separation frequency unevenly.

Consider now vector B having a phase-shift of, say 90°, this means that the sum of vectors A and C must not be added directly to vector B but in quadrature

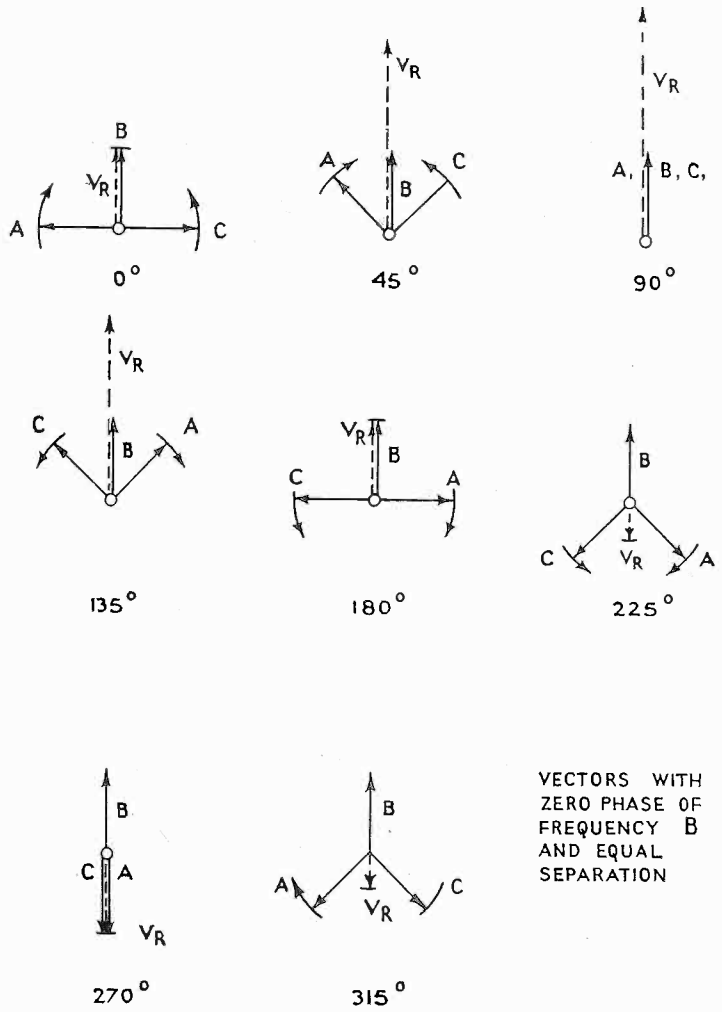
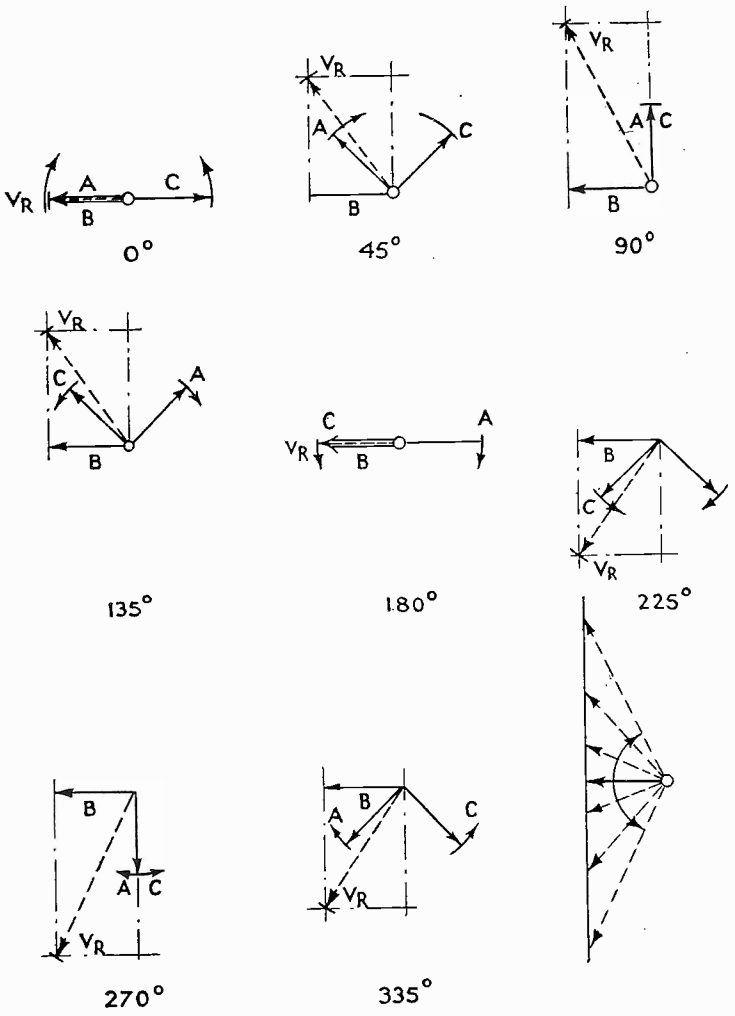


FIG. 13.

as shown in Fig. 14. Because of this the vector resulting from vector B and the sum of vectors A and C is a vector V_R which changes its position relatively to vector B, at one time leading it and at one time lagging it. In fact there is a to and fro' cyclic variation at the difference frequency of the position of this resulting

vector. Since vector B is a mean frequency of the group of vectors, it is clear that the resultant wave is no longer constant in frequency, but varies cyclicly at the difference frequency, this frequency variation being additional to the cyclic change of amplitude. That is to say, that phase-shifting one of the waves of such a group



VECTORS WITH 90° PHASE SHIFT OF VECTOR B AND EQUAL SEPARATION

FIG. 14.

has the effect of changing the amount of amplitude modulation and producing a frequency modulation. Further it is clear, by studying the vector diagram of Fig. 13, that the amount of frequency modulation introduced, shown by the swinging to and fro' of the resultant vector V_R, will increase as the amplitude of the outer

frequencies A and C increase. If now we consider unequal frequency separation it is clear that our rotating vectors can be considered as a group in which the centre one no longer retains its mid-position but gradually changes ; hence there will be a succession of vector pictures similar to the pictures of the equally spaced vectors with different phase shifts. This means we have a cyclic change of both amplitude and frequency modulation, changing through the series. A résumé of the results obtained by this graphical synthesis indicates that in general the waveforms predominating will be twice the main separation frequency and the separation frequency ; in addition the difference frequencies, i.e., the difference of separation are also present. Since all these waves are rectified envelopes and are generally peaky in character, there will be a whole series of harmonics present whose amplitude will depend principally upon the relative amplitudes of the original high frequency waves. In fact, the predominance of any of the difference frequencies depends entirely on the phase and amplitude of the original carriers being combined. Since the separation frequencies are made above the telephony speech band the amplitudes at which these are received is unimportant, but what is important is their difference, as this appears as an envelope. With the mid-frequency strong in amplitude compared with the others, the tendency will be for the difference frequency to become most prominent, because it is under this condition that the separation frequencies are most prominent.

PART IV.

Experimental Verification.

To carry the investigation one step further, three high frequency carrier waves were set up and collected on a receiver capable of accepting all three carriers simultaneously, and the rectified output from this receiver circuit was examined for harmonic content by means of a tone generator equipment, beats being obtained when harmonics were matched to a given tone.

The main features which have already been discussed were easily verified by this experimental method, and the existence of the L.F. difference tone proved. An attempt was made to measure this difference frequency and compare it with the separation frequencies of the carriers being combined, and some evidence was obtained that this beat difference might not be quite a simple function of these original separation frequencies. Further, evidence is required as to whether or not this effect is genuine, as the exactness of the measuring equipment was hardly adequate for the precision of the frequencies being measured.

Résumé.

So far we have merely considered the beating of un-modulated carriers, and it is clear that when each of these carriers are modulated, some slightly different result must be expected. It is well known that a low frequency tone can mask higher frequencies, and for this reason it would appear legitimate to assume that the low frequency separation tone would seriously interfere with modulation, should it be of value to come within the speech band. The higher frequencies would not be material, and even if they were present it is most probable that they would be completely masked by the lower frequency speech band during modulation.

With respect to the original proposal for the three transmitters with separations of 7 kc., case (A) Part I. will most nearly represent the working conditions.

Now postulating a limited band of audible transmitted frequencies for telephonic speech, say 250-2,750 hertz, it is clear that if the transmitters do not vary in frequencies the audible interference notes will all be above 2,750 hertz, and may be removed via a low pass filter. Should variation take place from this definite separation, there will be present a low note, increasing in frequency the greater the deviation from the original separation becomes. For practical purposes, this note may be taken as the difference frequency between the two separations. We shall now require to introduce a band pass filter to prevent both this low note and the still present high notes from causing interference. Now it will become evident that it will not be permissible for the low note to exceed some 100 hertz in any given case. Since one transmitter may drift in an opposite direction to another, the permissible variation for each transmitter is 50 hertz.

Now this conclusion is independent of frequency of transmission, and hence the greater the transmission frequency, the greater must be the inherent stability of the transmitter. At 3,000 metres 50 hertz deviation represents a constancy of 1 in 2,000, while at 30 metres it represents a constancy of 1 in 200,000.

It will thus be seen that while the service would be possible, it would require a particularly high class of constancy, particularly on the shorter waves.

We have not attempted to deal with the interference pattern created in space by the radiation from three such carrier waves, but this point has already been discussed for the case of two transmitters, by P. P. Eckersley,* when he showed that there were a number of zones in which weak or no signals would be received. Presumably a similar effect to this will be obtained when three carriers are considered.

A. W. LADNER.

H. J. H. WASSELL.

* "Common Wave Broadcasting," by P. P. Eckersley and A. B. Howe, J.I.E.E., June, 1927.

MARCONI NEWS AND NOTES

NEW B.B.C. HIGH-POWER TRANSMITTER.

THE British Broadcasting Corporation has placed an order with the Marconi Company for a high-power broadcasting transmitter to be installed in the new B.B.C. station which is now planned to take the place of the Daventry long-wave station.

The transmitter has been designed by the Marconi Company in close co-operation with the engineers of the B.B.C., and will incorporate some interesting new features, including a new system of modulation, known as "series modulation," and high-power valves capable of dealing with very large inputs.

The power rating of the station will be 100 kilowatts unmodulated carrier energy, and modulation up to 90 per cent. is arranged. Faithful and lifelike reproduction of vocal and musical programmes will be assured by a frequency characteristic which will be straight between 30 and 10,000 cycles.

Marconi Veterans' Fifth Annual Reunion.

THE Fifth Annual Reunion and Dinner of Members of the staff of the Marconi Company and its Associates, of 25 years' service or more to their credit took place at the Criterion Restaurant on the 26th November, 1932. Mr. Andrew Gray was in the Chair, and Veterans from all over the country and abroad made a great effort to be present. Marchese Marconi had arranged his return from Italy in time for the function, but an unforeseen delay prevented him from attending. Telegrams and letters of greeting and regret for absence were received from Marchese Marconi, Sir Ambrose Fleming, Marchese Solari, Mr. M. Travailleur and others.

The gathering stood for a few moments in memory of the late Mr. R. F. Cave, a Veteran of 1898, who died during the year.

Following the toast of the King, the Chairman proposed the toast of His Excellency, Marchese Marconi, and read out a telegram of greeting and good wishes for the success of his researches which he proposed to send to the Marchese on behalf of the Veterans. The toast of new members was proposed in an excellent speech by Mr. H. W. Allen and was responded to by Mr. G. E. Turnbull, who enlivened the proceedings by a number of personal reminiscences of members who were present. The toast of absent members was proposed by Mr. H. E. Watterson, who paid a tribute to the late Mr. R. F. Cave. The toast of the Chairman was proposed by

1895

His Excellency Marchese Marconi.

1897.

Col. H. Jameson Davis, H. W. Allen, G. S. Kemp,

1898

P. W. Paget, C. E. Rickard,

1899

W. Densham, Andrew Gray, H. M. Dowsett, R. T. Munson, F. S. Stacey,

F. Woodhouse, C. S. Franklin, P. J. Woodward, A. B. Blinkhorn, M. Travailleur, G. Périer,

1900.

W. H. Corby, R. N. Vyvyan, A. J. Clark, F. Archer, J. Harvie Clark,

Sir Ambrose Fleming, A. H. Atkinson, E. E. Triggs,

1901.

W. S. Entwistle, W. J. Willey, G. H. Green, A. Eve, Capt. C. V. Daly, G. Pells, E. G. Tyler,

F. E. D. Pereira, F. K. May, A. H. Ginman, A. Vanderpooten, R. Poupart, H. E. Dunn, F. Huff,

1902.

E. Berry, W. F. Thomas, R. D. Bangay, F. E. Burrowes, W. Davies, Capt. H. J. Round,

H. A. Ewen, E. C. Richardson, A. A. Kift, J. Lewis, H. E. Watterson, R. G. Newman, W. M. Sampson.

1903.

D. W. Tulloch, J. R. Stapleton, F. Jones, J. Harvey, A. J. Huff, H. T. Worrall, E. T. Hills, L. Verbrugghen

1904

H. J. Tattersall, A. J. Irvene, T. Iddon, W. A. Taylor, W. I. McGhee,

J. R. Robinson, W. Platt, W. J. Collop, W. N. Ball. F. S. Hayburn,

A. Cappelaere, W. Tasker, H. Cornwall. F. Delasse, W. J. Gray

1905

S. C. Parish, J. N. Johnson, W. B. Cole. E. J. Wagstaff. C. A. Manson,

C. A. Mason, H. M. Burrows, C. James, F. W. M. Herring. P. Treacy.

A. C. Lewis. G. Ludwig, D. Macdonald, F. R. Pells, E. Horton

1906.

C. J. Ketteridge, Marquis L. Solari, F. Beatson, A. J. Chesterton E. Hill,

A. M. Young, D. Sutherland, S. Stansbridge, Seton Smith, A. Ashley, W. Rogers,

F. Baker, S. C. Hills, C. C. Howe, H. D. Humphries, R. Leith, J. C. Hawkhead,

S. Kent. A. Fournier. A. Maernoudt. Annie König, M. J. Tasteney, R. C. A. Kroes.

1907.

H. Caswell. C. G. Rattray, T. Cox, J. H. T. Leggett. J. Connell, J. T. Marler, R. Cox. T. H. Stubbs,

E. J. Moore, C. Newer, H. Nicholls, G. E. Turnbull, A. Hubert, E. C. Montague, A. Cobham

Mr. A. H. Ginman, who spoke of the services rendered to the Marconi Company, particularly in the early years, by Mr. Gray. He mentioned that Mr. Gray was responsible for the first Imperial scheme of wireless submitted to the Colonial Office in 1906, and described how he settled in characteristic manner, to the relief of the operators, the question of the unpaid messages incurred when the first unofficial chess match at sea was played between two ships on the New York passage. The Chairman suitably replied.

A musical programme arranged by Miss Nellie O'List added to the enjoyment of a very pleasant evening.

The arrangements were made by the Hon. Secretary, Mr. H. M. Dowsett, assisted by the Hon. Treasurer, Mr. W. J. Collop, and Mr. W. Platt acted as Chief Wine Steward.

Wireless Over Africa.

FOLLOWING tests carried out by the British Air Ministry and Imperial Airways Limited, four of the new "Atalanta" type aircraft for the Cairo-Cape Town air route are to be fitted with Marconi apparatus.

The type of equipment adopted, known as the Type A.D.37a/38a, is capable of reliable transmission and reception of telephony and telegraphy on either medium or short wavelengths, covering the dual wavebands of 40-80 and 500-1,000 metres. It has been specially developed by the Marconi Company as the result of an extensive series of practical tests carried out over a period of six months over the actual air route, investigating the whole question of the utility of medium and short wavelengths for air-to-ground and ground-to-air communications under the difficult conditions prevailing in the equatorial districts of Africa.

During tests, record long distance two-way communication was established with the British Post Office station at Portishead, near Bristol, while the Marconi-equipped aircraft was in the air over the White Nile, 5,000 miles away. Other long distance contacts of this nature were also maintained with Norddeich, Germany, at 5,000 miles, and Coltano, Northern Italy, at 3,900 to 4,000 miles, while news messages were received on short waves from the wireless station at Miami Beach, U.S.A.

In addition to the new Marconi apparatus for telephone and telegraph communication, the "Atalantas" are to be fitted with Marconi-Robinson directional receiving equipment. This takes the form of a small attachment to the A.D.38a receiver, providing a simple and convenient direction finding service.

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